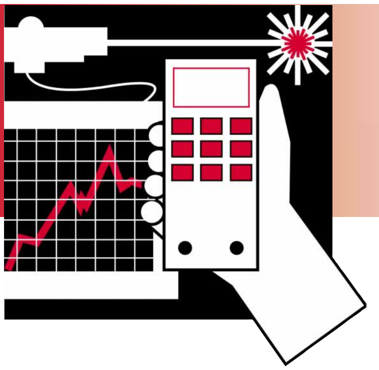
SENSORS & CONTROLS

Project Fact Sheet



Portable Parallel Beam X-Ray Diffraction System

Benefits

- Development of a small, low-power, parallel beam XRD system capable of operating in the harsh environments of a steel mill
- Increased x-ray intensity of up to 100 times current XRD systems
- Decreased power consumption from the current XRD system requirements (2,000 to 18,000 watts) down to 100 watts
- Improved measurement efficiency by an order of magnitude over the conventional Bragg-Brentano geometry
- Reduced system sensitivity to sample displacement and general defocusing errors
- Increased system utility and portability: weight will be decreased from current XRD systems (200 to 1,000 kg) down to 20 kg, and volume will be decreased from current 2 m^3 down to 0.04 m^3

Applications

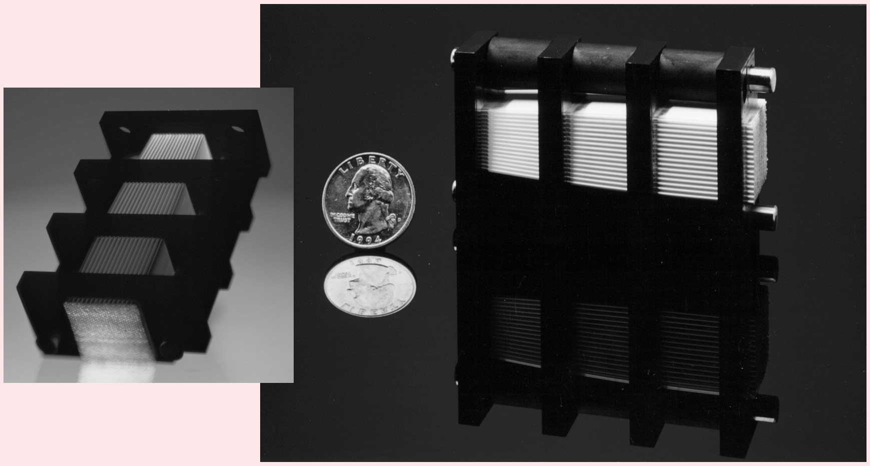
The use of a parallel beam XRD approach can be applied to in-line monitoring of phase, grain size, grain orientation (texture), and residual stress of steel. Grain shape and orientation are of fundamental interest in microalloy steels. These parameters essentially determine drawability of the steel, which is of great concern to the automotive industry. Numerous applications exist in rolling and finishing slab. Continuous in-line monitoring of material properties using XRD will improve yield, decrease power requirements, and improve quality for a wide range of industries including steel, aluminum, cement, and pharmaceuticals.

In-line x-ray diffraction will allow real-time process control in metal manufacturing

Real-time, nondestructive, in-line measurements of material properties are needed for process control in metallurgical manufacturing. With the incorporation of newly developed x-ray optics, x-ray diffraction (XRD) can be used to identify structural phases, determine grain size, and measure stress and texture of materials in line. XRD is widely used in laboratories to determine these material properties, but current XRD techniques cannot be used for in-line monitoring as they require sophisticated sample preparation, weigh hundreds of pounds, require water cooling, and consume several kilowatts of power. The proposed system to be developed through this project will provide real-time material characterization capability, be portable, weigh no more than 50 pounds, and use about 100 watts of power.

The subject technology uses capillary x-ray optics to collect x rays over a large solid angle from a low-power x-ray source and to form an intense parallel beam. This system will eliminate the problem of misalignment and provide significantly more intensity than current Bragg-Brentano XRD systems. The parallel beam geometry will also eliminate the instrument error functions that contribute to asymmetric peak shape broadening: flat specimen, axial divergence, sample displacement, and sample transparency.

Multifiber Polycapillary Optic



This project is developing a compact in-line XRD system to perform fast identification and quantification of phases (chemical compounds), grain sizes, residual stress, and texture in steels for process control.

Project Description

Goal: Develop a compact in-line XRD system to perform fast identification and quantification of phases (chemical compounds), grain sizes, residual stress, and texture in steels for process control.

The analysis of unprepared, inhomogeneous samples requires a large, high-flux beam to measure the average composition. The conventional means to produce a parallel x-ray beam is a pinhole collimator. These collimators use only a tiny fraction of the output beam from the x-ray source, and current x-ray sources do not provide sufficient brilliance to address the problem.

This project will investigate the feasibility of a powder XRD system for in-line process control in the steel industry with a conventional low-power, air-cooled tube x-ray source and polycapillary optics. A recent invention, polycapillary optics have demonstrated capabilities both in collimating and focusing x rays. The proposed system will use one collimating polycapillary optic, collecting a large solid angle off the x-ray tube, and will redirect the x rays into a two-dimensional collimated beam of 10 by 10 mm that will be delivered to the sample. The optic is expected to deliver an order of magnitude more flux on the sample than a graded multilayer optic and about two orders of magnitude more flux than a pinhole collimator.

This novel, parallel beam XRD unit will be evaluated for in-line microstructure characterization with an initial focus on the needs of rolling and finishing slab. A compact breadboard XRD unit, owned by X-Ray Optical Systems, Inc., will be modified for use in this evaluation. LTV Steel, Inc., will provide a set of samples representing the range of good and bad production steels relevant for the selected measurement. The samples will be characterized using both parallel beam and Bragg-Brentano systems for comparison. Results obtained will be the basis for a functional design of a parallel beam diffraction system based on polycapillary x-ray optics.

Progress and Milestones

- This project was selected through the Sensors and Controls Program, FY99 Small Business Innovation Research (SBIR) Phase I solicitation, in July 1999. Phase I project tasks will be completed in six months.
- In related research, the developer has already fabricated and tested a multifiber polycapillary optic. This optic is being used commercially for structure analysis, by x-ray diffraction, of thin magnetic films used for computer hard disks.
- During the Phase I project, measurements will be carried out on different samples using an existing breadboard parallel beam diffraction system with a polycapillary x-ray optic. This system will be modified as needed, and work will lead to design of a prototype system for fabrication during Phase II.
- During Phase II and Phase III, a prototype system will be built and tested. This system should be able to detect retained austenite at one percent by volume and above. The angular range for these measurements will be 70-165° 2θ. The monitoring speed of individual phases and phase changes should be adequate to modify processing conditions.

Project Partners

LTV Steel Technology Center
Independence, OH

John Stubbles
Grafton, WI

X-Ray Optical Systems, Inc.
Albany, NY

For Additional Information, Please Contact:

Eric Lightner
Office of Industrial Technologies
Phone: (202) 586-8130
Fax: (202) 586-1658
Eric.Lightner@ee.doe.gov
www.oit.doe.gov/crosscut/sens_cont

Please send any comments, questions, or suggestions to webmaster.oit@ee.doe.gov.

Visit our website at www.oit.doe.gov.

Office of Industrial Technologies
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, D.C. 20585

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